

*PREFERENCE AFTER TRAINING WITH
DIFFERENTIAL CHANGEOVER DELAYS*

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Pigeons were trained on a multiple schedule in which each component consisted of concurrent variable-interval (VI) 30-s VI 60-s schedules. The two components of the multiple schedule differed only in terms of the changeover delays (COD): For one component short CODs were employed, and in the second component long CODs were used. After approximate matching was obtained in each component, probe tests involving new combinations of stimuli were presented (e.g., the VI 30-s schedule from each component) to determine how the different CODs affected preference. Despite shorter CODs producing higher changeover rates, the COD value had no systematic effect on preference on the probe trials. However, differences in reinforcement rate always produced preference for the schedule with the higher reinforcement rate. The results thus show that the pattern of changeover behavior per se is not a critical determinant of choice in the probe-trial procedure.

Key words: choice, changeover delay, concurrent schedule, key peck, pigeons

An enduring problem in the analysis of choice has been the identification of the critical controlling variables. A variety of different hypotheses have been advanced, including relative rate of reinforcement (Herrnstein, 1970), momentary probability of reinforcement (Shimp, 1966; Silberberg, Hamilton, Zirbax, & Casey, 1978), molar reinforcement rate summed over the choice alternatives (Baum, 1981; Rachlin, Battalio, Kagel, & Green, 1981), local rate of reinforcement (Herrnstein & Vaughan, 1980), and relative time to reinforcement (Gibbon, Church, Fairhurst, & Kacelnik, 1988; Mark & Gallistel, 1994).

Williams and Royalty (1989) attempted to distinguish between some of these different hypotheses by determining whether choice was controlled by the scheduled reinforcement rates or by the local reinforcement rates. Pigeons were trained on a multiple schedule in which different concurrent schedules operated in each component. In Component A, choice was between VI 20-s and VI 120-s schedules; in Component B, choice was between VI 60-s and VI 80-s schedules. Training continued until matching of relative response rate to relative reinforcement rate occurred in both components. As discussed elsewhere (see Williams, 1988), matching in a concurrent schedule equalizes

the local rates of reinforcement for both members of a concurrent pair of schedules. Thus, both the VI 20-s and VI 120-s alternatives were associated with local rates of reinforcement of approximately 210 reinforcers per hour, whereas both the VI 60-s and VI 80-s alternatives were associated with local rates of reinforcement of approximately 105 reinforcers per hour. Then, during probe trials, the subjects chose between the stimuli correlated with the VI 60-s and VI 120-s schedules. Whereas the scheduled absolute rate of reinforcement favored the VI 60-s alternative, the obtained local reinforcement rate favored the VI 120-s alternative. Preference during the probes was in favor of the VI 60-s alternative. The same general pattern of results, using discrete-trials procedures, was obtained by Williams (1993).

The results of our earlier studies thus seemed to exclude local rate of reinforcement (or probability of reinforcement, which is equivalent for discrete-trials procedures) as the controlling variable, and suggested that either molar relative rate of reinforcement or relative time to reinforcement was the critical variable. However, a related study by Belke (1992) reveals a major difficulty for both of these hypotheses. In his study pigeons chose between a VI 20-s and a VI 40-s schedule during one component of a multiple schedule, and between a VI 80-s and a second VI 40-s schedule in a second component. The two stimuli correlated with the different VI 40-s schedules were then presented together dur-

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ing probe tests, with the result that the VI 40-s schedule that had been paired with the VI 80-s schedule was strongly preferred over that previously paired with the VI 20-s schedule. According to accounts based on the relative time to reinforcement (or relative rate of reinforcement), no differential preference should have occurred, because the two schedules had identical distributions of interreinforcement intervals (Mark & Gallistel, 1994).

Mark and Gallistel (1994) argued that Belke's (1992) data were consistent with control by relative time to reinforcement, if the assumption were made that the probability of changeovers between the schedules of a concurrent pair, established during training, was transposed to the probe procedure. Thus, relative time to reinforcement did not control preference directly, but only as mediated by the establishment of different interchangeover times for the two VI 40-s schedules.

Gibbon (1995) has developed a similar account, but with a more elaborate theoretical rationale for why different rates of changeover behavior occur. Following Myerson and Miezin (1980), he assumed that the rate of changeover behavior in a given component of the multiple schedule is directly proportional to the total reinforcement rate in that component. The presumed mechanism of this effect is that higher arousal levels (which are proportional to reinforcement rate) regulate the frequency of decisions about staying versus switching with respect to a given choice alternative, so that high reinforcement rates (the VI 20-s VI 40-s pair in Belke's 1992 experiment) produce more frequent decisions, which means that the subject will be more likely to switch away from the VI 40-s schedule paired with the richer alternative schedule. To test this hypothesis, Gibbon replicated Belke's results and added probe tests between the VI 20 s and the VI 40 s that had been paired with the VI 80 s. The results were that preference was in favor of the VI 40 s, which was predicted on the basis of the different changeover rates with respect to the two schedules. Gibbon thus argued that the addition of the concept of arousal allows the notion of relative time to reinforcement to account for Belke's results.

The importance of the frequency of changeover behavior established during training has been demonstrated directly by

Williams and Bell (1996). They replicated Belke's (1992) procedure, but with the modification that the VI 20-s schedule was changed to a signaled VI 20-s schedule in which a keylight change occurred whenever the temporal interval scheduling the next reinforcer had elapsed. This meant that response rate to the signaled VI 20-s schedule was low except when the signal was present, which resulted in the interchangeover times to the VI 40-s schedule from the the unsignaled VI 20-s schedule being much longer than in the original unsignaled procedure. The results of probe tests between the two VI 40-s schedules were then reversed from Belke's original findings: Preference was in favor of the VI 40-s alternative that had been paired with the signaled VI 20-s alternative.

The possibility that the pattern of changeover behavior may interact with other variables has been suggested by Zentall, Weaver, and Sherburne (1996), in conjunction with their value-transfer theory of simultaneous discrimination learning. The essence of their theory is that the value of the S+ (or stimulus with the higher reinforcement rate) transfers to the value of the S-. Thus, stimulus value is determined at least partly by the total amount of reinforcement in the presence of a stimulus. Because this hypothesis is apparently contradicted by Belke's (1992) findings, Zentall et al. repeated Belke's procedure with the modification that the schedule pairs were VI 20 s versus VI 80 s and VI 40 s versus VI 80 s. The two VI 80-s schedules were then presented together during probe tests, the result of which was preference for the VI 80-s schedule that had been paired with the VI 20-s alternative. Note that both of the stimuli presented during the probe trials were associated during training with the lesser valued schedule of their concurrent pair, which presumably made the pattern of changeovers during training more similar, and thus allowed control by the reinforcement variables, independent of changeover rate, to be revealed. Zentall et al. thus argued that Belke's original results obscured the control by reinforcement variables because of the confounding bias of different response patterns in the two components of the schedules. However, Zentall et al. made no direct comparison between their procedure and that reported by Belke, so it remains uncertain exactly what role was

played by the different patterns of changeover behavior.

The present study further investigates the role of the pattern of changeover behavior in assessments of preference. Here we attempted to manipulate directly the changeover rates within a component of a multiple schedule by varying the duration of the changeover delay (COD). Past research has shown that the probability of changeovers is greater with shorter CODs (Shull & Pliskoff, 1967). In our experiment the pair of schedules within each component of the multiple schedule was identical (concurrent VI 30 s VI 60 s). During one component short CODs were in effect (1 and 2 s), and in the second component longer CODs were in effect (2 and 4 s). As will be seen, this manipulation generated substantially shorter interchangeover times in the short-COD component. The issue is whether presentations of probe tests involving similarly valued schedules (the two VI 60-s schedules or the two VI 30-s schedules) would reflect the different interchangeover times produced by the different CODs. A further question is whether the effect of different interchangeover times produced by the different CODs was similar to that when the different interchangeover times were produced by differences in reinforcement schedules. To make this comparison, probe tests were also conducted in which one of the VI 30-s schedules was paired with one of the VI 60-s schedules.

METHOD

Subjects

Eight experimentally experienced pigeons (*Columba livia*) were maintained at 80% of their free-feeding body weights by additional feeding, when necessary, after each experimental session. All were housed in individual cages with water and grit freely available. Free-feeding weights were calculated by providing all pigeons with continuous access to both milo and pigeon chow for a period of at least 2 weeks prior to assessing free-feeding weights. All birds then were weighed daily for 7 days. The results were used to calculate a mean free-feeding weight. The pigeons' mean 80% weight was 472 g, with a range of 402 to 726 g.

Apparatus

Experimental chambers consisted of opaque black plastic side walls, sheet aluminum front and back walls, a plywood ceiling, and a wire mesh floor. Each chamber was 32 cm high, 35 cm wide, and 36 cm deep and had three response keys, each 2.5 cm in diameter, mounted 23 cm from the floor and 7.25 cm apart, center to center, on the front wall. Each response key could be transilluminated from the rear and required a minimum force of approximately 0.15 N to operate. Access to a solenoid-operated grain hopper, when activated, was available through a rectangular opening 5 cm high and 6 cm wide, located 9.5 cm below the center key. Reinforcers consisted of 3-s access to milo. While the hopper was raised, it was illuminated by a white light, and the keylights were extinguished. General chamber illumination was provided by a white houselight mounted 4 cm above the center key. A ventilation fan and continuously present white noise masked extraneous sounds. Scheduling of experimental events and data recording were performed by IBM clone computers programmed using Borland's Turbo Pascal and located in an adjacent room.

Procedure

Baseline training. All subjects had experience with similar procedures and were placed directly into the baseline procedure, in which they were exposed to a multiple schedule with alternating 8-min components. Components were separated by a 10-s timeout period, during which all keylights in the chamber were extinguished and the houselight remained illuminated. Key pecks during this timeout had no effect.

During both components of the multiple schedule, concurrent VI 30-s VI 60-s schedules operated. All VI schedules were programmed according to the Fleshler and Hoffman (1962) distribution. The first component was randomly determined prior to each session. A changeover-key procedure (Findley, 1958) was used. This procedure is a concurrent schedule, but the stimuli associated with each schedule are not presented simultaneously. Instead, subjects must explicitly respond on a separate changeover key. Alternation between choice alternatives is

still controlled by the subject, as it is in simple concurrent choice procedures, but the changeover key explicitly separates schedule responses from changeover responses.

During Component A of the multiple schedule, a 2-s COD was in effect for changes from the VI 60-s schedule to the VI 30-s schedule, and a 1-s COD was in effect for changes from the VI 30-s schedule to the VI 60-s schedule. For Component B of the multiple schedule, a 2-s COD was in effect for changes from the VI 60-s schedule to the VI 30-s schedule, and a 4-s COD was in effect for changes from the VI 30-s schedule to the VI 60-s schedule.

When a response was made to the illuminated changeover key, the stimulus on the main reinforcement key changed immediately to the other component of the concurrent schedule, and the changeover key was darkened and remained ineffective until a response was made to the new stimulus on the schedule key and the appropriate COD for that alternative elapsed. The COD timer restarted when the bird made a response to the dark changeover key, but the changeover key was not illuminated (and responses were ineffective) until a response was made on the main key.

The operant response contingency was always presented on the center key. The VI 30-s schedule in Component A was always correlated with a blue keylight. The VI 60-s schedule in Component A was correlated with a red keylight for half the subjects and with a green keylight for the other half. The VI 30-s schedule in Component B was always correlated with a white keylight, and the VI 60-s schedule in Component B was correlated with a red or green keylight, which was the opposite assignment from that in Component A. The changeover key was always correlated with a yellow stimulus presented on the left key.

Choice was judged, based on visual inspection of relative response rates, to be stable for all subjects after 37 to 46 baseline sessions.

Probe preference tests. After stability had been achieved, probe trials were incorporated into the baseline procedure. They consisted of 1-min presentations of three probe types. The probes were presented in the same fashion as baseline components except that the schedule-stimulus combinations were novel and

key pecks could no longer produce food. During probe trials no COD requirement was employed. Two baseline sessions (without probes) were conducted between each session that included probe tests. Probe trials occurred after every two alternations of the baseline components in which food was available. Eight probe sessions were presented for each probe type. Subjects were exposed to three probe types, with only one probe type being presented during any given probe session. The first probe type presented subjects with a choice between the stimuli correlated with the two VI 30-s schedules of reinforcement. The second probe type presented subjects with a choice between the stimuli correlated with the two VI 60-s schedules of reinforcement. The final probe type presented subjects with a choice between the stimulus that had been correlated with the VI 30-s schedule in Component A and the stimulus that had been correlated with the VI 60-s schedule in Component B. That is, a stimulus that should have evoked a relatively high rate of changing-from, due to the short COD in training (i.e., VI 30 s in Component A) was pitted against a stimulus that should have evoked a relatively low rate of changing-from, due to the long COD in training (i.e., VI 60 s in Component B). Thus, the predicted preference based on the changeover rates established during training is opposite in direction from that based on the relative rate of reinforcement during training. The order of presentation for the different probe types was counterbalanced across subjects.

After completion of the first set of probe tests, subjects were returned to the baseline condition for 10 additional sessions. A second set of probe trials was incorporated into the baseline procedure and was presented in the same manner as before, with the modification that only five probe sessions were conducted and only one baseline session separated probe sessions. Also, here only two probe types were presented. The first type was a replication of the third probe type used in the first set of probe tests, in that subjects were presented with a choice between the VI 30-s schedule from the short-COD component and the VI 60-s schedule from the long-COD component. The second type of probe presented subjects with a choice between the VI 30-s schedule from the long-COD compo-

Table 1
Results from the last 10 sessions of baseline and from the first set of probe tests.

Subject	Responses per minute				Changeover rates		Probe preferences		
	30 s	60 s	30 s	60 s			30 s	60 s	30 s
	short	short	long	long	Short	Long	short vs. 30 s long	short vs. 60 s long	short vs. 60 s long
W-54	66.2	27.8	74.7	38.4	6.8	4.7	.59	.46	.77
R-39	93.0	50.7	122.8	55.4	10.9	6.1	.55	.38	.57
W-21	93.8	34.1	132.5	37.2	8.2	7.2	.77	.74	.60
B-64	59.7	35.3	82.6	95.3	14.7	8.9	.53	.39	.63
R-22	54.5	48.6	81.0	26.2	15.8	6.2	.30	.51	.54
R-63	71.3	26.4	82.5	38.4	10.6	6.0	.64	.44	.55
R-11	143.1	53.4	101.2	77.6	10.3	6.2	.69	.54	.56
R-61	47.8	36.7	68.9	29.0	13.4	8.3	.39	.44	.63
<i>M</i>	78.7	39.1	93.2	49.7	11.3	6.7	.56	.49	.61

nent and the VI 60-s schedule from the short-COD component. The two types of probes were alternated across probe sessions. Subjects W-54, R-11, and B-64 were exposed first to a choice between the VI 30-s schedule from the short-COD component and the VI 60-s schedule from the long-COD component. The remaining 4 subjects received the opposite order of presentation.

RESULTS

Table 1 shows the response rates averaged over the last 10 sessions of baseline, at which time responding in both components of the multiple schedule was judged to be stable. The total response rates summed over the two choice alternatives were slightly higher in Component B in which the VI 60-s schedule was associated with a 4-s COD (hereafter referred to as the long-COD component) than in Component A in which the VI 60-s schedule was associated with the short COD (143 responses per minute vs. 118 responses per minute), but a correlated-means *t* test showed that this difference was not statistically significant, $t(7) = 2.40$.

Preference for the VI 30-s schedule was calculated for each component. Despite the fact that considerable deviations from matching occurred for individual subjects (e.g., Subject B-64), the mean preference levels were identical for both components (.66). Thus, the different COD values had no systematic effect on the degree of preference.

It is important to recognize that the asymmetrical COD arrangements used in the two

components should have produced systematic differences in preference if the basis of COD effects is that short CODs provide more immediate reinforcement for changeovers. Thus, in the short-COD component, changeovers from the VI 30-s to the VI 60-s schedule could be reinforced after only 1 s, whereas in the long-COD component, the delay to reinforcement after a changeover to the VI 60-s schedule was 4 s. Thus, the strength of changeover responding to the VI 60-s schedule should have been greater in the short-COD component, which should have increased preference for the VI 60-s alternative. The degree of preference for the VI 30-s schedule should correspondingly have been less in the short-COD component than in the long-COD component. As seen in Table 1, however, such differences did not occur.

Despite the fact that the differences in COD values had no effect on the degree of preference, they did systematically affect the rate of changeovers. To calculate changeover rate, the total number of changeovers in each component was divided by the total time in that component. The results of this calculation are also shown in Table 1. For all 8 subjects, changeover rate was higher in the short-COD component than in the long-COD component. Thus, the COD manipulation was effective in changing the pattern of behavior across the two components even though both components involved the same concurrent VI 30-s VI 60-s schedule values and had the same degree of preference for the VI 30-s schedule.

The results of the first set of probe tests are

also shown in Table 1. The results are aggregated over all eight sessions of each probe type because there was no systematic change over probe sessions in the degree of preference. For the first probe, in which the stimuli correlated with the two VI 30-s schedules were presented together, the mean preference for the schedule in the short-COD component was .56. A simple t test showed that this degree of preference was not significantly different from indifference (.50), $t(7) = 1.06$. For the second probe, involving the stimuli of the two VI 60-s schedules, the mean preference for the schedule in the short-COD component was .49, which also is not significantly different from indifference. Thus, even though very different changeover rates occurred in the short-COD and long-COD components, this difference in the pattern of changeovers had no systematic effect on the preference revealed during the probe trials.

The third type of probe trial paired the VI 30-s schedule from the short-COD component with the VI 60-s schedule from the long-COD component. This pitted the effect of the reinforcement schedule against that of the COD. Here the mean preference level for the VI 30-s schedule was .61, which was significantly different from indifference, $t(7) = 4.03$, $p < .05$.

Although the COD had no systematic effect on the mean level of preference on the probe trials, some differences did appear when the results were subjected to a correlational analysis. For a given probe pair, the response rates during baseline training were summed over both alternatives, and then the proportion of that total for each response alternative was calculated (i.e., a relative rate of responding was calculated even though the two alternatives had never appeared together during the baseline training). The relative response rates during baseline were then correlated with the preference results from the probe trial. For the VI 30-s versus VI 30-s probe, Pearson's r was .48; for the VI 60-s versus VI 60-s probe, it was .24, and for the VI 30-s versus VI 60-s probe, it was $-.23$. None of these values attained statistical significance (with 6 df , the .05 level of significance is .71). Thus, the response rate established during training was a poor predictor of preference on the probe trials.

A similar correlational analysis related the

preference results during probes to the relative changeover rates in the two components of the multiple schedule corresponding to the components from which the different probe alternatives were drawn. Here the VI 30-s versus VI 30-s probe yielded a correlation of $-.78$, the VI 60-s versus VI 60-s probe yielded a correlation of $-.53$, and the VI 30-s versus VI 60-s probe had a correlation with relative changeover rate of $-.33$. Thus, unlike response rate, the changeover rates did correlate with the probe preference results, as long as the probe alternatives did not differ in their schedule of reinforcement during training. The best interpretation of these negative correlations is that subjects that were most sensitive to the COD manipulation, as indexed by the ratio of changeover rates in the two components, were least likely to have preference scores favoring the schedule from the short-COD component that was associated with shorter interchangeover times.

After completion of the first set of probe sessions, subjects were returned to their home cages for several weeks and then resumed training on the baseline condition for 10 additional sessions. (Note that 1 pigeon, R-61, died during this hiatus.) The results of this set of 10 baseline sessions are shown in Table 2. In general, the results from this return to baseline were essentially similar to those from the first period of baseline training, shown in Table 1. Preference in the short-COD component was again .66, and preference in the long-COD component was .68. Changeover rates in the two components were also very similar to the changeover rates obtained during the initial baseline training.

After the 10 new sessions of baseline, the new set of probes was administered. One type of probe was identical to third type of probe described above (i.e., the VI 30 s from the short-COD component vs. the VI 60 s from the long-COD component). The second type of probe was the alternative combination of the VI 30-s and VI 60-s schedules. The rationale behind this new comparison was to isolate the contribution of the different CODs from that of the different rates of reinforcement. Given that the reinforcement schedules were the same for the two types of probes, any difference between them would be ascribed to the CODs used in training. Thus, the VI 30-s schedule should be less pre-

Table 2

Results from the second set of 10 baseline sessions and from the second set of probe tests.

Subject	Responses per minute				Changeover rates		Probe preferences	
	30 s short	60 s short	30 s long	60 s long	Short	Long	30 s short vs. 60 s long	30 s long vs. 60 s short
W-54	70.2	34.5	68.4	18.0	9.3	5.7	.58	.75
R-39	76.6	47.3	100.5	48.1	11.2	5.2	.74	.78
W-21	68.3	66.2	94.2	34.5	9.0	5.7	.80	.47
B-64	109.3	49.9	87.7	41.7	11.3	6.5	.80	.82
R-22	73.6	38.6	75.3	37.4	11.3	5.8	.69	.79
R-63	68.6	28.6	71.6	34.1	12.3	8.2	.72	.64
R-11	99.0	29.1	68.3	62.7	10.3	7.1	.86	.70
<i>M</i>	80.8	42.0	80.9	39.5	10.7	6.3	.74	.71

ferred when the probe trials involved the VI 30 s from the short-COD component in combination with the VI 60 s from the long-COD component. In addition, the overall level of preference across both probe types indicates the role of the reinforcement schedules used during training.

The results from the second set of probe trials are also shown in Table 2. Preference for the VI 30-s short COD over the VI 60-s long COD was .74, somewhat higher than the .61 obtained for the same type of probe test in the first set of probes shown in Table 1. The preference for the VI 30-s long-COD schedule over the VI 60-s short-COD schedule was .71, which was not significantly different from the results of the first probe type. Note that any contribution of changeover rate to preference on the probe tests predicts a higher preference score from the second type of probe, because the VI 30-s schedule from the short-COD component should have generated shorter interchangeover times due to its higher changeover rate. Thus, preference should have been lower when the VI 30-s component from the short component was paired with the the VI 60-s component from the long-COD component. However, this prediction is in the opposite direction of what actually occurred. For both types of probes there was a strong preference for the VI 30-s schedule, indicating that the value of the schedule was the major determinant of the value of the different stimuli correlated with the various schedule components.

Figure 1 shows the distribution of dwell times during the baseline phase of the second stage of training, presented in the same for-

mat as comparable data in Gibbon (1995). Dwell times were measured as the times allocated to a given choice alternative after a changeover before returning to the other alternative. Each individual dwell time was individually recorded, and the sum of dwell times for a given 2-s interval was divided by the total number of dwell times for a given choice alternative. Clear differences in the distribution of dwell times were produced by the different COD durations. For both the VI 30-s and VI 60-s schedules, the schedule from the short-COD component produced many more short dwell times than the comparable schedule from the long-COD component, consistent with the different rates of changeover behavior seen in Table 2. It is important to recognize that the COD requirement constrained the distribution of dwell times differentially in the two components. Because changeovers were not allowed until the COD requirement had been fulfilled, dwell times less than 4.0 s could not occur for the VI 60-s schedule in the long-COD component, whereas only dwell times less than 1.0 s were prevented for the VI 60-s schedule in the short-COD component. Thus, the difference in the shape of the dwell-time distributions in the bottom two quadrants of Figure 1 is primarily due to this procedural constraint. In order to see how dwell-time distributions differed apart from this constraint, the distribution from the long-COD component must be displaced to the left. With such displacement, considerable overlap in the distributions from the two components becomes evident. Differential constraints due to the COD requirement was not a factor for the VI

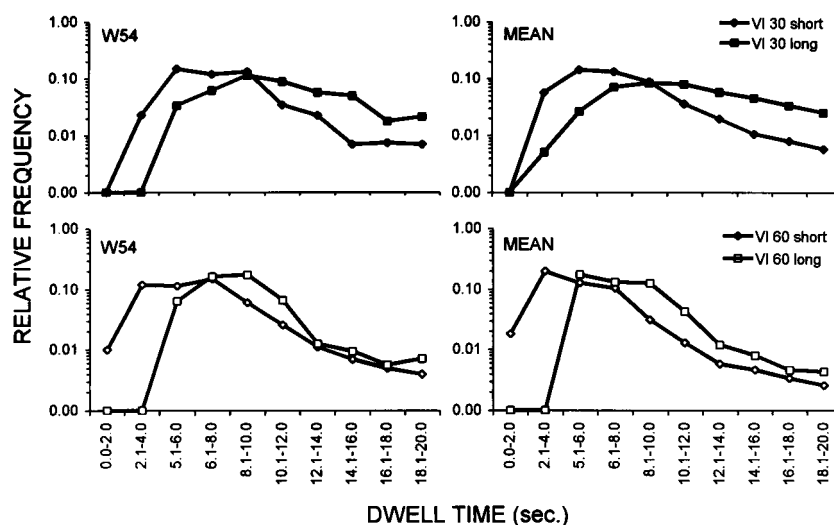


Fig. 1. The distribution of dwell times from the baseline sessions of the second phase of training, corresponding to the conditions shown in Table 2. Because of the log scale used on the ordinate, the value of zero corresponds to an actual value of .001, and any obtained relative frequencies lower than .001 were plotted as .001. A representative subject is shown in the left two panels; the mean of all 7 subjects is shown in the right two panels. The different functions in each panel correspond to the same schedule value but are from the components with short versus long CODs.

30-s schedules, in that the COD requirement following a switch to either VI 30-s schedule was 2.0 s. Thus, the differences in dwell-time distribution for the short-COD and long-COD components seen in the top two quadrants reflect the differences in changeover rates produced by the different COD values associated with the different VI 60-s choice alternatives.

Figure 2 shows the distribution of dwell times from the probe trials, during which no COD requirement was in effect. The probertial data for the individual subject, W-54, are very ragged, especially for the longer dwell times, due to the small number of observations available for analysis. For the mean data, however, systematic effects are evident. For the VI 30-s choice components, the distribution of dwell times was similar to that during baseline for the shortest dwell times, although it is displaced to the left because of the removal of the COD constraint. Beyond the short dwell times, the distribution largely overlapped during the probe trials, whereas many more long dwell times occurred during baseline training in the long-COD component. For the VI 60-s components, the distribution of dwell times from the two components was also displaced to the left due to the

removal of the COD constraint, and then overlapped much like it did during baseline. Thus, there were minor differences in the distribution of dwell times independent of the schedule constraints for the VI 60-s schedule, whereas systematic differences in the dwell-time distribution as a function of the COD value did occur for the VI 30-s schedule during both baseline and probe testing.

DISCUSSION

The purpose of the present study was to determine to what extent the pattern of preference scores obtained on probe trials like those used in previous studies (Belke, 1992; Gibbon, 1995; Williams & Bell, 1996; Williams & Royalty, 1989) was due simply to the pattern of changeovers established to the different stimuli during baseline training. If the results during the probe trials were due solely to the subject transposing the changeover rates (or conversely, the interchangeover times) associated with a given stimulus to the probe trials, any experimental manipulation that altered the changeover rates should affect the preference measure obtained on the probe trials. In the present experiment, in which the COD value was used to vary the

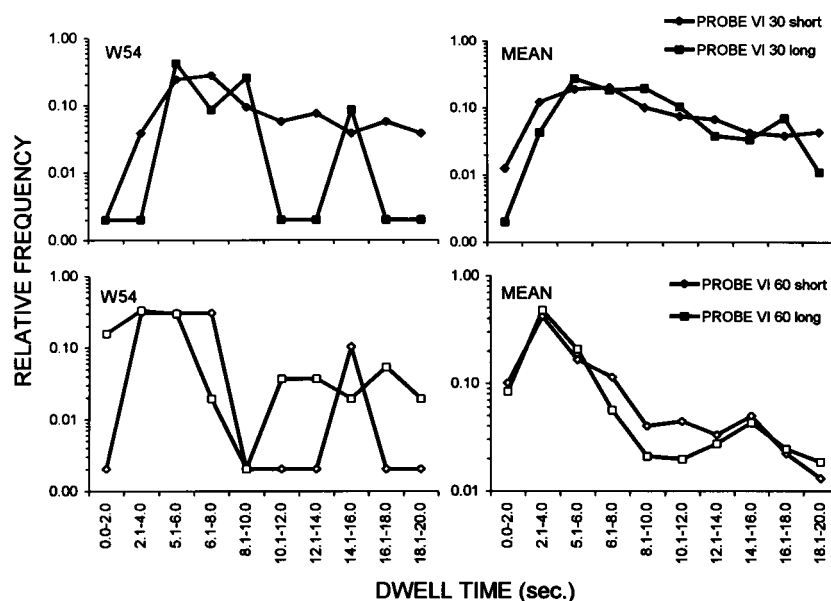


Fig. 2. The dwell times during the probe sessions of Phase 2. Because of the log scale used on the ordinate, the value of zero corresponds to an actual value of .001, and any obtained relative frequencies lower than .001 were plotted as .001. A representative subject is shown on the left; the mean of all 7 subjects is shown on the right.

changeover rates, the prediction was that the schedules associated with the shorter COD value, which produced almost double the changeover rate, would be less preferred than the schedule associated with the longer COD. No evidence was obtained for such an effect, in that preference during probe trials was determined by the value of the reinforcement schedules independent of the CODs (and the rates of changeover) that had been correlated with the different stimuli during baseline training. Preference is therefore not simply the result of switching rates away from a given stimulus established during training. The failure of the different COD values to affect preference occurred despite the fact that the differences in the distribution of dwell times that occurred during baseline in the two components of the concurrent schedule continued to be evident during the probe trials, at least for the VI 30-s choice alternatives.

The failure of the different COD values to affect the probe preference results in the present study is seemingly in conflict with the results of Williams and Bell (1996), who reported that the pattern of preference on probe trials was reversed when the pattern of changeover behavior was altered by the use

of a signaled VI schedule. That is, the procedure replicated that of Belke (1992), with a concurrent VI 40-s VI 20-s schedule in one component and a concurrent VI 40-s VI 80-s schedule in the second component. The simple replication of Belke's procedure produced results similar to his, in that the VI 40-s schedule that had been paired with the VI 80-s schedule during training was strongly preferred in probe tests over the VI 40-s schedule that had been paired with the VI 20-s schedule. However, when the VI 20-s schedule was converted to a signaled VI 20-s schedule, thus greatly reducing the changeover rate in that component, the preference pattern for the two VI 40-s schedules was reversed.

The conflict between the present results and those of Williams and Bell (1996) implies that the different ways of altering changeover behavior are not equivalent. Possibly this was due to changeovers to the signaled VI 20-s alternative being under stimulus control of the signal presentation, such that one pattern of changeovers occurred in the absence of the signal and a different pattern occurred after the signal was presented. Such stimulus control could occur because a typical two-key concurrent schedule was used rather than the

Findley changeover procedure that was used in the present study. Because the probe tests were conducted in the absence of the signal itself (because no reinforcement was available on probe trials), it is possible that the effective reinforcement rate was also under stimulus control. Thus, when the VI 40-s schedule was concurrent with the absence of the signal for reinforcement availability on the other key, the sum of the reinforcement rates in the presence of the VI 40-s stimulus was simply that from the VI 40-s schedule itself. In contrast, in the alternative component in which the second VI 40-s schedule was concurrent with the VI 80-s schedule, the sum of the reinforcement rates in the presence of the VI 40-s schedules was the sum of the reinforcement rates from both schedules. Thus, the VI 40-s stimulus paired with the extinction stimulus from the signaled VI 20-s schedule would be associated with a lower reinforcement total summed over the two choice alternatives than was the VI 40-s schedule paired with the unsignaled VI 80-s alternative. If, as argued by Mark and Gallistel (1994) and Gibbon (1995), changeover rate is positively related to the total reinforcement rate summed over both choice alternatives of a given stimulus condition, the lower functional rate of reinforcement when the VI 40-s schedule was paired with the extinction stimulus of the signaled VI 20-s schedule would have reduced the rate of changeovers during that component, not because of any direct discriminative action of the signal contingency in determining changeover rate but because during most of the time during training the rate of reinforcement in the concurrent VI signaled 20-s VI 40-s component was functionally lower than in the concurrent VI 20-s VI 40-s component.

The preceding analysis of the results of Williams and Bell (1996) is consistent with the analysis provided by Gibbon (1995). According to his account, behavior during probe trials is determined by two factors: the distribution of interreinforcement intervals, which determines the value of the different schedules, and the arousal level associated with a given stimulus, which determines the rate of decisions about staying versus switching between choice alternatives, and which is directly associated with the sum of the reinforcement rates across both choice alterna-

tives during training. As applied to the present results, Gibbon's analysis implies that there should have been no difference in the arousal level in the two components of the multiple schedule, because identical concurrent VI 30-s VI 60-s schedules were used in both components. Thus, the rate of stay-or-switch decisions should have been similar for both components, so that the only factor determining preference on the probe trials was the distribution of interreinforcement intervals. Accordingly, when the schedule values for a given probe pair were equal, no differential preference was observed, but when the alternatives in the probe pairs were associated with different reinforcement schedules during training, the preference scores for all subjects favored the stimulus that had been correlated with the higher rate of reinforcement. The different changeover rates produced by the different CODs had no impact on the results of the probe tests because the COD value presumably did not affect the rate of stay-or-switch decisions. Thus, only the schedule value was important, which resulted in indifference when either the two VI 30-s or the two VI 60-s schedules were presented together, but strong preference was shown for the VI 30-s schedule when it was paired with the VI 60-s schedule, regardless of the COD value associated with the different schedules during training. The implication is that there are multiple ways of producing differences in the rate of changeovers, but only those due to differences in reinforcement rates play a role in determining the results of the probe tests.

This is not to say that differences in changeover rates established by means other than different reinforcement rates play no role in preference. The difference between the results of Zentall et al. (1996) and Belke (1992) seems to require an explanation in terms of differences in changeover behavior, although exactly what those differences were has not been clearly specified. Likewise, in the present study, a negative correlation between changeover rate and preference was obtained across subjects for the probe tests involving the two VI 30-s schedules. This suggests that those subjects that were most sensitive to the COD differences were also the subjects with the greater degree of preference. Also problematic are the differences in the dwell-time distributions for the two VI 30-

s schedules shown in Figure 2. The different COD contingencies during baseline produced substantially more short dwell times during the probe trials for the VI 30-s schedule from the short-COD component, and yet the overall choice proportions were not sensitive to these differences. The cause of the apparent disparity between the preference data and the evidence of continuing influence of the COD contingencies during probe-trial performance is an enigma.

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REVIEW EDITOR

Typically, book reviews in *JEAB* provide more than critical evaluations of particular books. They are occasions for examining the nature of behavior analysis, often by considering relations with other scholarly fields. The review editor's role in developing these essays is crucial. Philip N. Hineline has served with distinction as review editor since 1992. In addition to nurturing many book reviews during his term, Phil coedited an annotated collection of *JEAB*'s reviews (*Variations and Selections: An Anthology of Reviews from the Journal of the Experimental Analysis of Behavior*) and served as action editor for several sets of papers on theoretical issues (e.g., January 1996; March 1997; September 1997). Phil asked to retire as review editor at the end of 1998 so that he could give more attention to other scholarly pursuits.

I am pleased to announce that M. Jackson Marr has agreed to become review editor effective January 1999. Jack is known as a perceptive scholar with wide-ranging interests. If you are considering writing a book review for *JEAB*, it would be helpful to contact the review editor at an early point to discuss the suitability of the review and prospects for publication. You should send a brief description of your plans to M. Jackson Marr, School of Psychology, Georgia Institute of Technology, Atlanta, GA 30332 (E-mail: mm27@prism.gatech.edu).

Richard L. Shull
Editor